Summary

12–1 DNA

To understand genetics, biologists had to learn the chemical structure of the gene. Frederick Griffith first learned that some factor from dead, disease-causing bacteria turned harmless bacteria into disease-causing ones. Griffith called this process transformation. Griffith thought that the transforming factor might be a gene. Oswald Avery and his research group later found that DNA was the transforming factor. Alfred Hershey and Martha Chase also showed that genes are made of DNA.

Scientists began studying the structure of DNA to learn how it can carry information, determine an organism's traits, and replicate itself. DNA is a long molecule made up of units called nucleotides. Each nucleotide is made up of a 5-carbon sugar, a phosphate group, and a nitrogen-containing base. There are four kinds of bases: adenine, guanine, cytosine, and thymine.

James Watson and Francis Crick discovered that DNA is shaped like a double helix, or a twisted ladder, in which two strands are wound around each other. The two strands are held together by hydrogen bonds between adenine and thymine and between guanine and cytosine. The sugar phosphate backbone makes up the sides of the ladder.

12–2 Chromosomes and DNA Replication

Single-celled organisms without a nucleus have DNA in the cytoplasm. Most have one circular DNA molecule. In organisms with a nucleus, DNA is in the nucleus. The DNA is organized into different numbers of chromosomes, depending on the organism.

DNA molecules are very long. To fit inside cells, they must be tightly folded. The DNA in a chromosome is wound around proteins, called histones. The DNA and histones wind together to form nucleosomes.

Before a cell divides, it copies its DNA in a process called replication. The DNA molecule separates into two strands. Then, two new strands form, following the rules of base pairing. Each strand of the DNA molecule serves as a template, or model, for the new strand.

Many enzymes carry out DNA replication. One enzyme, called DNA polymerase, joins individual nucleotides to produce the DNA molecule. It also checks that the correct nucleotide is added.

12–3 RNA and Protein Synthesis

In order for a gene to work, the genetic instructions in the DNA molecule must be decoded. The first step is to copy the DNA sequence into RNA. RNA makes it possible for a single gene in a DNA molecule to make hundreds of copies.

RNA has a structure like DNA, except for three differences: (1) The sugar in RNA is ribose instead of deoxyribose; (2) RNA is single-stranded; and (3) RNA has uracil in place of thymine.

Three kinds of RNA molecules work together to make proteins. Messenger RNA has the instructions to put together amino acids to make a protein. Proteins are put together on ribosomes. Ribosomes are made up of proteins and ribosomal RNA. Transfer RNA carries each amino acid to the ribosome according to the coded message in messenger RNA.

RNA is copied from DNA in a process called transcription. The enzyme RNA polymerase binds to DNA and separates the two strands. Then, RNA polymerase builds a strand of RNA using one strand of DNA as the template. The sequence of DNA that signals RNA polymerase where to bind and start making RNA is called the promoter.

The instructions for making proteins are found in the order of the four nitrogenous bases. This code is read three letters, or nucleotides, at a time. Each codon, or group of three nucleotides, specifies a certain amino acid that makes up a protein. In the genetic code, some amino acids are specified by more than one codon. One codon is a start signal for translation. Three codons signal the end of translation.

Translation is the process in which the genetic code in RNA is used to make proteins. Translation takes place on ribosomes. Before translation can begin, messenger RNA is transcribed from DNA. Then, the messenger RNA moves into the cytoplasm and attaches to a ribosome. As each codon of the messenger RNA moves through the ribosome, the proper amino acid is brought into the ribosome by transfer RNA. The ribosome joins together each amino acid. In this way, the protein chain grows. When the ribosome reaches a stop codon, it falls away from the protein chain and the messenger RNA molecule. Transcription has ended.

12–4 Mutations

Mutations are changes in the sequence of DNA. Gene mutations are changes in a single gene. Chromosomal mutations cause changes in whole chromosomes. Gene mutations that occur at a single point in the DNA sequence are called point mutations. When a point mutation causes one base to replace another, only one amino acid is affected. If a nucleotide is added or taken away, it causes a frameshift mutation. All the groupings of three nucleotides, or codons, are changed. This can cause the gene to produce a completely different protein.

In a chromosomal mutation, there is a change in the number or the structure of chromosomes. There are four kinds of chromosomal mutations: deletions, duplications, inversions, and translocations.

12–5 Gene Regulation

Genes can be turned on and off when proteins are needed. In prokaryotes, some genes are turned on and off by a section of a chromosome called an operon. An operon is a group of genes that work together. Two sequences of DNA in the operon that control when genes are turned on and off are the operator and the promoter. When the cell needs a certain protein, RNA polymerase attaches to the promoter and produces a messenger RNA that is translated into the needed protein.

When the cell no longer needs the protein, it makes another special protein called the repressor. The repressor attaches to the operator, blocking the promoter so that RNA polymerase cannot attach to it. This turns the genes of the operon off.

In eukaryotes, there are several ways of turning genes on and off. One system uses a protein that binds directly to DNA. This either starts or increases the transcription of certain genes.